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In re the Application of:
Satyavolu, et al.

Serial No. 09/689,994 Group Art Unit : 1731
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FOR: ENHANCED FIBER ADDITIVE; AND USE

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Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

DECLARATION UNDER 37 C.F.R. 1.132

I, Kevin R. Anderson, declare that my educational background is as follows:

Master of Science, North Dakota State University (1986)
Research Activities – Organosilane Reactive Intermediates
Thesis – Di-t-butylsilylene; Reaction and Products

Bachelor of Arts, University of Minnesota, Morris (1979)
Major in Chemistry

Since my graduation, my employment was as follows:

2000-Present	Director of Technology Development, North America, Cargill Industrial Starches
1995-2000	Research and Development Manager, Cargill Food and Industrial Starch.
1991-1995	Team Leader, Cargill Industrial Starch
1986-1991	Research Chemist, Cargill, Inc.
1984-1986	Research Chemist, Warner Lambert

I am a co-inventor of the invention described in the above-identified U.S. Patent Application Serial No. 09/689,994.

Under my immediate supervision, Example I of U.S. Patent No. 5,023,103 issued to S.R. Ramaswamy was reproduced by Mr. J. Steinke, to determine the composition of the fiber said to have been produced. The procedure of Example 1 was followed as closely as possible, and the conditions are described herein for the processing of raw oat hulls as shown in Example 1.

The following reaction was performed in a Parr pressure reactor model number 4522-M-SS-VS-1000-4843EB with a 1/8 hp motor and turbine-style impellers. A Teflon liner was installed in the pressure vessel to protect the stainless steel walls from corrosion. The total volume of the reactor was 1500 mL with the liner installed. The quantity of reactants was scaled down to about 1000 mL to accommodate for the expansion of the reaction mixture.

The reactants were mixed outside of the pressure vessel in a 2000 mL polypropylene beaker. To the beaker was added 947 mL of water and 85 mL of 50% NaOH solution. A quantity of 227 g of raw oat hulls was slowly blended into the NaOH solution with continuous stirring. The slurry became increasingly more viscous. By the end of the oat hull addition the consistency was reminiscent of cookie dough. The color of the oat hulls progressed from a light tan powder to a yellowish-orange dough. The raw oat hulls were previously ground in a Retsch mill to pass through a 30 mesh (opening = 0.6 mm) screen.

The oat hull dough was rolled into the shape of a cylinder and dropped into the Teflon sleeve. The reactor was sealed and inserted into the heater. Heat was applied to the vessel and the stirrer adjusted to 500 rpm. A minimum of 500 rpm was necessary to provide consistent agitation of the reaction mixture. The heater set point was 165°C. After about 1.75 hours the vessel reached 150°C. A few minutes later the vessel pressure achieved 65 psi and the reaction timer was started.

At the end of the two-hour reaction period, the temperature had reached 159°C. Excessive pressure was relieved during the reaction to maintain 65 psi. The contents of the vessel were cooled to 65°C by running tap water through the internal coils.

A vacuum filtration system was set up using a Buchner funnel, Whatman #4 filter paper, and a filtration flask. The pressure vessel was opened and the contents poured onto the filter paper. The digest was brown, about as viscous as molasses, and the odor reminiscent of black liquor from a pulp mill. There was no visible evidence of fibers. For at least 30 minutes no liquid came through the filter. After about one hour there was a significant flow of liquor through the funnel. The filter paper had begun to disintegrate.

The digest was diluted one part liquor to nine parts water in an effort to locate fibers. No fibers were visibly observed in the diluted solution. About 100 mL of the digest was neutralized to approximately pH 7.0. The digest became slightly cloudy and lighter in color. The cloudy precipitate, however, did not resemble fibers. The gelatinous precipitate was isolated by filtration and upon closer examination resembled fatty acids.

In conclusion, it is apparent that following the procedure described in Example 1 of U.S. Patent No. 5,023,103 does not produce any solid fibers. Rather, it produced homogeneous liquor or digest.

From the above experimentation, there was not obtained any solid fibrous product. Rather, the digestion procedure that was utilized resulted in the dissolution of all of the oat hulls. As a result, there was not obtained any solid fiber that could be analyzed to determine the amounts of cellulose and hemicellulose.

The undersigned declares further that all statements made herein on his own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with a knowledge that willful, false statements, and the like so made are punishable by fine, or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issues thereon.

November 18, 2004
Date

Kevin R. Anderson

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I certify that this paper (along with any referred to as being attached or enclosed) is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Commissioner of Patents, Mail Stop Amendment, Alexandria, VA 22313-1450.	
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Properties of Nonwood Fibers[*1]

James S. Han[*2]

ABSTRACT

Nonwood or agro-based fibers are a potential source of pulping material. However, these fibers have tremendous variations in chemical and physical properties as compared to wood fiber. This study presents some chemical and physical properties of nonwood fibers derived from selected tissues of various monocotyledonous and dicotyledonous plants. Properties were compared for different fiber lengths at different growth stages and plant stalk heights.

1. INTRODUCTION

In general, fibers can be classified into three categories: wood, nonwood, and nonplant. The term "nonwood" was coined to distinguish plant fibers from the two main sources of wood fibers. hardwoods and softwoods. Non-wood or agro-based fibers are derived from selected tissues of various mono- or dicotyledonous plants (Parham & Kausftinen, 1974) and are categorized botanically as grass, bast, leaf, or fruit fibers.

Some nonwood fibers are classified by means of production; fibers such as sugar cane bagasse, wheat straw. and corn stalks are byproducts. Other nonwood fibers are grouped as "fiber plants," plants with high cellulose content that are cultivated primarily for the sake of their fibers such as jute, kenaf, flax, cotton. and ramie. Some fiber plants also produce useful byproducts; for example, oils from kenaf and flax seed.

Nonwood fibers can be used to make paper, although the quality varies a great deal depending on the source of the fibers. Combining wood with nonwood fibers can reduce the amount of chemicals needed for pulping as well as shorten pulping time, thus saving energy. The high cellulose content of cotton linter (85% to 90%) compared to that of wood (35% to 49% cellulose) and the low lignin content of hemp (3%) make these nonwood fibers valuable for papermaking. Although there are some drawbacks to nonwood pulping, most nonwood fibers are bulky and vulnerable to biological deterioration during storage.

2. CHEMICAL PROPERTIES

Data reported on the chemical properties of nonwood fibers vary greatly. Studies have varied in fiber source, fiber age (growing time), and methodology. The data on the chemical composition of some common nonwood fibers shown in Table 1 were reported by Parham and Kausftinen (1974).

Table 2 shows lignin composition of selected nonwood fibers compared to content of ash and selected

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*1 Part of this paper was presented as Fiber Property Comparison at the TAPPI 1998 North American Nonwood Symposium at Atanata, GA, February 17~18 Co-sponsored by USDA Forest Service and USDA Biobased Products Coordination Council.

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Table 1. Chemical Composition of Some Common Non-wood fiber Compared to Wood Fiber.

Fiber type	Chemical composition (% total)				
	Cellulose	Lignin	Pentosan	Ash	Silica
Stalk					
Rice	28~48	12~16	23~28	15~20	9~14
Wheat	29~51	16~21	26~32	4.5~9	3 ~ 7
Barley	31~45	14~15	24~29	5~7	3 ~ 6
Oat	31~48	14~19	27~38	6~8	4~6.5
Rye	33~50	14~19	27~30	2~5	0.5~4
Cane					
Sugar	32~48	19~24	27~32	1.5~5	0.7~35
Bamboo	26~43	21~31	15~26	1.7~5	0.7
Grass					
Esparto	33~38	17~19	27~32	6~8	-
Sobai	-	22	24	6	-
Reed[a]	44~46	22~24	20	3	2
Bast					
Seed flax	43~47	21~23	24~26	5	-
Kenaf	44~57	15~19	22~23	2~5	-
Jute	45~63	21~26	18~21	0.5~2	
Hemp	57~77	9~13	14~17	0.8	-
Ramie	87~91		5 ~ 8		
core					
Kenaf	37~49	15~21	18~24	2~4	-
Jute	41~48	21~24	18~22	0.8	
Leaf					
Abaca[b]	56~63	7~9	15~17	3	-
Sisal[c]	47~62	7~9	21~24	0.6~1	
Seed hull[d]	85~90	0.7~1.6	3~Jan	0.8~2	1
Wood					
Coniferous	40~45	26~34	7~14	< 1	-
Deciduous	38~49	23~30	19~26	< 1	-

Notes: [a] Phragmites communis, [b] Manila, [c] Agave. [d] Cotton linter.

sugars. In general, the higher the lignin content, the lower the cellulose content. Since cellulose is a homopolysaccharide composed of (-D-glucopyranose units linked together by (IR4)-glucosidic bonds and since only fractions of glucose units are expected to be derived from hemicellulose, high glucose content generally represents high cellulose content in chemical analysis. Nonwood hemicellulose is mostly arabinoglucuronoxylan and/or glucuronoxylan. Thus, a high percentage of xylose is an indication of high hemicellulose content. On the basis of xylose content, bagasse, coconut shell, purple top, and big bluestem have the highest hemicellulose content of the nonwood fibers listed in Table 2. More data on the chemical properties of nonwood, hardwood, and softwood fibers have been reported by Han and Rowell (1997).

Chemical properties are influenced by fiber growth time(days after planting), botanical classification of fiber. and stalk height.

Table 2. Chemical Composition of Some Common Nonwood Fibers by Order of Decreasing Lignin Content

Fiber type	Chemical composition (% total)[a]							
	Lignin	Ash	Glu	Ara	Gal	Pha	Xyl	Man
Peat moss	45.90	1.10	19.16	0.25	2.54	1.19	2.77	2.35
Coconut shell	35.72	-	25.91	0.29	0.32	0.21	23.93	0
Cocount fiber	33.50	-	34.87	0.05	0.36	0.16	16.98	0.12
Sheet moss	30.20	11.50	18.46	1.37	5.44	1.24	1.34	7.27
Flax shive	27.80	-	34.89	0.28	0.73	0.32	18.50	1.99
Acacia	26.00	-	41.99	1.37	0.49	0.28	15.46	1.72
Jute core	24.77	0	39.09	0.11	0.41	0.38	17.35	0.91
Flax	22.90	-	31.21	1.17	1.77	0.62	12.29	1.13
Sunn hemp, core	22.74	0	41.46	0.26	0.73	0.27	17.08	1.94
Rice hull	21.40	16.30	33.89	1.52	0.85	0.05	13.95	0.16
Bagasse	19.87	0.25	43.10	1.93	0.55	0	24.019	0.18
Velvet leaf core	19.61	0	40.61	0.29	0.73	0.49	18.333	0.75
Spanish moss	19.50	1.90	29.54	4.61	4.86	0.23	15.04	0.72
Kudzu bark	19.30		36.55	2.93	2.04	0.54	4.95	1.09
Purple top	18.86	2.77	31.96	2.85	1.13	0.72	20.25	0.18
Little bluestem	18.79	2.41	35.05	3.03	1.18	0.12	18.19	0
Kenaf core	18.30		33.45	0.49	0.83	0.29	14.24	1.01
Big bluestem	18.17	2.48	34.19	2.88	1.20	0.27	19.57	0.20
Spagnum moss	16.60	1.90	29.54	4.61	4.86	0.23	15.04	0.72
Tobacco	16.46	0.53	33.16	0.63	0.80	0.472	12.40	0.92
Kudzu	15.70	-	39.40	1.81	1.67	0.57	11.36	0.69
Lechugilla	15.21	0	41.84	0.45	1.03	0.14	17.33	0
Loofa	13.60	-	56.38	0.24	0.36	0.15	14.89	0.17
Jute fiber	13.73	0.14	56.87	0.11	0.49	0.16	12.17	0.50
Hibiscus elantus	12.60	-	55.98	0.58	0.70	0.29	9.01	0.29
Abaca	12.66	0.19	52.69	1.83	1.03	0.16	12.81	0.89
Banana pinzota	11.10	1.20	43.24	3.85	1.47	0.34	10.66	1.82
Sunn hemp, base fiber	11.14	0.23	56.38	1.08	2.05	0.29	1.97	2.99
Kenaf	9.88	-	43.32	2.04	0.46	1.25	10.80	1.25
Tobacco bark	9.69	0	27.42	1.46	1.33	0.62	8.42	0.90
Velvet leaf	9.03	0.12	34.37	1.89	1.67	0.77	8.95	0.98
Agave cantala	6.80	0.23	55.79	0.42	1.24	0.46	12.83	0.82
Pineapple	4.60	0.10	64.35	0.90	0.71	0.06	12.04	0.20
Hesperaloe funifera	4.09	0.01	37.88	1.85	1.75	0.41	7.39	3.43
Hemp, Chinese	3.00	0.40	83.81	1.34	2.11	0.79	1.92	3.03
Hemp, degum	2.50	0.10	83.81	0.26	1.34	0.18	1.18	1.87

Notes: [a] L-arabinose(Ara), L-rhamnose(≤*f*). L-galactose(gal), D-mannose(Man), D-glucose(Glu), D-xylose(Xyl)

2.1 Fiber Growth Time

Using kenaf as the model. an intensive study was conducted on changes in chemical and physical properties of nonwood fibers as a function of fiber growth time. The results led to the conclusion that the vast differences between sets of data can be explained by differences in fiber growth time(Table 3) (Han & Rowell, 1995 · 1997). As the kenaf fiber matures, lignin. glucose. and xylose content increase and anbinose, galactose, rhamnose, and mannose decrease. The pattern of extractives content apparent in Table 3 also occurred for fiber length. We speculate that extractives content differs at early and later stages of fiber

Table 3. Chemical Composition of Kneaf Bast Fiber as Function of Fiber Growth time.

DAP[a]	Chemical composition (% ovendry basis)							
	Extb	Lignin	Glu	Am	Gal	Rha	Xyl	Man
35	14.87	4.32	28.86	3.95	0.78	2.72	6.54	1.76
42	8.80	6.00	33.20	3.18	0.62	1.82	7.31	1.63
57	5.13	8.32	35.45	2.21	0.55	1.46	8.08	1.59
63	4.34	7.74	37.08	2.43	0.62	1.48	8.61	1.53
70	4.63	8.70	40.53	2.02	0.46	1.25	9.37	1.47
77	4.99	9.23	40.52	2.05	0.39	1.36	9.16	1.34
84	5.07	8.33	39.88	2.27	0.49	1.63	9.39	1.53
91	5.68	9.38	42.82	1.91	0.42	1.35	9.98	1.31
98	2.42	8.81	41.60	2.13	0.48	1.73	9.69	1.35
133	8.03	8.94	41.98	1.67	0.48	1.15	9.72	1.31
155	7.83	9.99	46.39	1.27	0.38	0.87	11.20	1.19
161	11.51	10.22	39.22	2.54	0.56	1.52	9.75	1.33
168	12.31	9.74	41.41	2.18	0.47	1.37	10.36	1.39
175	8.23	9.69	49.33	1.40	0.36	0.87	12.29	1.02

Notes: [a] Days after planting, [b] Extractives.

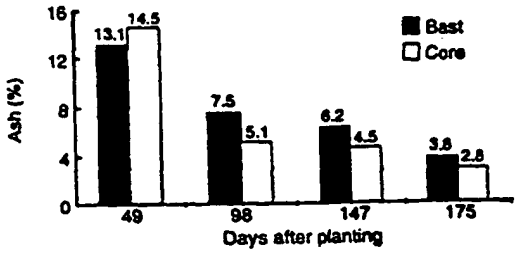

Fig. 1. Kenaf ash content as a function of growing time.

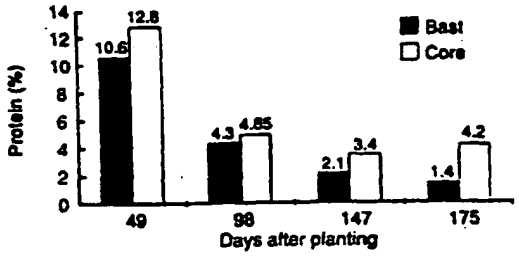

Fig. 2. Kenaf protein content as a function of growing time.

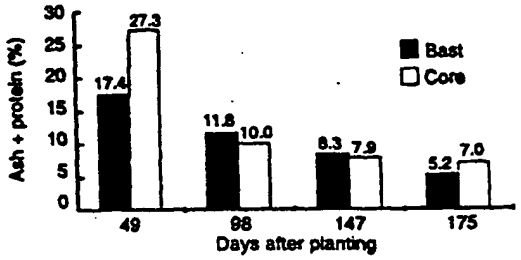

Fig. 3. Combined kenaf ash and protein content as a function of growing time.

growth.

The ash and protein content of the kenaf was also measured as a function of fiber growth (Fig. I -3). Combined ash and protein in the kenaf core was as much as 27% at 49 days after planting (DAP) and as little as 7% at 175 DAP.

The high protein content noticed early in the growth of kenaf is a fairly universal phenomenon in nonwood fibers. High protein content is believed to interfere with Klason lignin analysis. Since some types of protein are insoluble in acid, it is possible that the reported value for lignin could be higher than the actual value (TAPPI standard T-222). This problem in lignin analysis of nonwood fiber needs to be corrected in situations that warrant an equivalent of Klason lignin content.

2.2 Botanical Classification

Core and bast fiber are the two major botanical classifications of plant fibers. Other botanical classifications are root and stalk fiber. The lignin content of kenaf is higher in the core than in the bast fiber. The higher concentration of lignin in the core compared to other parts of the plant is true for many annual plants (Table 4). Lignin concentration can be twice as much in the core as in other plant parts. This high lignin content of core fibers is one of the most important factors that affect pulping of nonwood fibers.

Table 4. Chemical Composition of Fiber by Botanical Classification.

Fiber type	Botanical part	Chemical composition (%)						
		Lignin	Glu	Ara	Gal	Rha	Xyl	Man
Kenaf	Stalk fiber	9.88	43.32	2.04	0.46	1.25	10.80	1.25
	Root fiber	14.33	36.70	1.81	1.02	0.44	8.85	0.80
	Stalk core	18.30	33.45	0.49	0.83	0.29	12.24	1.01
	Root core	20.54	38.41	0.28	0.55	0.32	17.87	0.68
Velvet leaf	Fiber	9.03	34.37	1.89	1.67	0.77	8.95	0.98
	Core	19.61	40.61	0.29	0.73	0.49	18.33	0.75
Sunn hemp	Fiber	11.14	56.38	1.08	2.05	0.29	1.97	2.99
	Core	22.74	41.46	0.26	0.73	0.27	17.08	1.94
June	Fiber	13.73	56.87	0.11	0.49	0.16	12.17	0.50
	Core	24.77	39.09	0.11	0.41	0.38	17.35	0.91
Tobacco	Fiber	9.69	27.42	1.46	1.33	0.62	8.42	0.90
	Core	16.46	33.16	0.63	0.80	0.42	12.40	0.92

2.3 Stalk Height

Chemical composition can also vary within the same part of a plant. Both root and stalk core have high lignin content than that of fiber. Since kenaf can grow quite tall. we studied whether chemical content differs in the top and bottom parts of the stalk. Samples from the top of the stalk had lower lignin content than did samples from the bottom (Table 5).

Table 5. Chemical Composition of Kenaf at Top and Bottom of Stalk at Various Growth Times.

DAP	Stalk part	Chemical composition (%)						
		Lignin	Glu	Ara	Gal	Rha	Xyl	Man
42	Top	5.00	32.65	2.50	1.74	0.82	7.04	1.72
42	Bottom	6.50	36.01	2.75	1.50	0.74	8.50	1.48
57	Top	5.10	30.61	3.11	1.96	0.68	6.78	2.02
57	Bottom	9.00	38.18	2.49	1.47	0.45	8.93	1.35
77	Top	4.10	27.53	3.99	2.83	0.73	5.90	2.00
77	Bottom	19.10	36.71	0.34	0.61	0.37	17.48	1.12

3. PHYSICAL PROPERTIES

A notable physical difference between wood and nonwood fiber is that nonwood fibers are formed in aggregates or bundles. This is why nonwood fibers like cotton and flax can be used to make rope and textile. The fiber aggregates are polymers, with a single fiber unit representing the basic building block of the polymer.

Physical properties important to the understanding of non-wood fibers are fiber length and width, crystallinity, and permeability. Fiber length is the most important of the-se properties for pulping.

3.1 Fiber Length

Knowledge about fiber length is important for comparing different kinds of nonwood fibers. The length and width of some common nonwood fibers are shown in Table 6 (Isenberg, 1967). More information on this topic has been published by Han and Rowell (1997). Maximum length and width of some pitted vessel elements of common nonwood fibers (Pfaffli & Sisko, 1995) are shown in Table 7. Fiber length is an important factor **in** pulping. Methodology for measuring wood fiber length and fiber length data were reported in detail by Isenberg (1967).

Table 6. **Length** and Width of Some Common Nonwood Fibers

Common name (Scientific name)	Fiber length (mm)		Fiber width (mm)	
	Avg	Range	Ave	Range
Ramie (*Boehmeria nivea*)	120	60~250	50	11~80
Flax (*Linum usitatissimum*)	33	9~70	19	5~38
Hemp (*Cannabis sativa*)	25	5~55	25	10~51
Ceiba, kapok tree (*Ceiba pentandra*)	19	8~30	19	10~30
Cotton lint(*Gossypium* spp.)	18	10~40	20	12~38
Paper-mulberry (*Broussonetia papyrifera*)	10	6~20	30	25~35
Sunn (*Crotaria juncea*)	8	4~12	30	25~50
Abaca (*Musa textilis*)	6	2~12	24	16~32
Kenaf (*Hibiscus cannabinus*)	5	2~6	21	14~33
Sidal (*Agava Sislana*)	3	1~8	20	8~41
Bamboo (*Dendrocalamus arundinacea*)	2.7	1.5~4.4	14	7~27
Raphia (*Raphia hookeri*)	2.4	-	30	17~46
Sabai (*Eulaliopsis binata*)	2.1	0.5~4.9	9	4~28
Common reed (*Phragmites communis*)	2.0	1.0~3.0	16	10~20
Jute (*Corchrous caspsularis*)	2	2~5	20	10~25
Papyrus (*Cyperus papyrus*)	1.8	1.0~4.0	12	8~25
Sugar cane (*Sacchrum officiarum*)	1.7	0.8~2.8	20	10~34
Corn (*Zea mays*)	1.5	0.5~2.9	18	14~24
Rice (*Oriza sativa*)	1.4	0.4~3.4	8	4~16
Wheat (*Triticum sativum*)	1.4	0.4~3.2	15	8~34
Esparto (*Stipa tenacissima*)	1.2	0.2~3.3	13	6~22
Albardine (*Lygeum spartum*)	1.1	0.2~3.1	12	6~21

3.2 Relationship of fiber length to fiber growth stage.

Variation of wood fiber length can be expressed as a two-dimensional function of tree height and fiber **distance** from pith. We compared the fiber length of wood and nonwood fibers using red pine, aspen, and

Table 7. Maximum Length and Width of Pitted Vessel Elements in Common Nonwood Fibers

Common name (Scientific name)	Max length(mm)	Max width(mm)
Raphia (*Raphia hooker*)	5.0	350
Oil palm (*elaeis guineensis*)	4.0	300
Sugar cane (*Sacchrum officiarum*)	2.1	200
Common reed (*phragmites communis*)	2.0	120
Papyrus (*Cyperus papyrus*)	1.7	100
Bamboo (*Dendrocalamus strictus*)	1.0	250
Wheat (*Triticum sativum*)	1.0	60
Sabai (*Eulaliopsis binata*)	1.0	50
Rice (*Oriza sativa*)	0.8	70
Albardine (*Lygeum spartum*)	0.7	30
Corn (*Zea mays*)	0.6	120
Esparto (*Stipa tenacissima*)	0.4	40

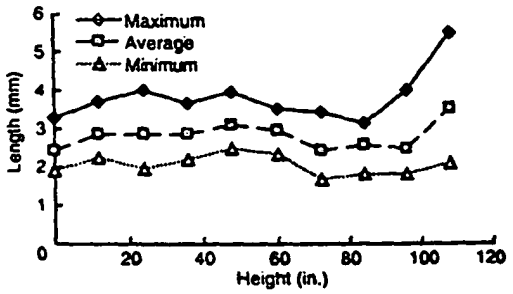

Fig. 4. Length of kenaf fiber at 147 days after planting.

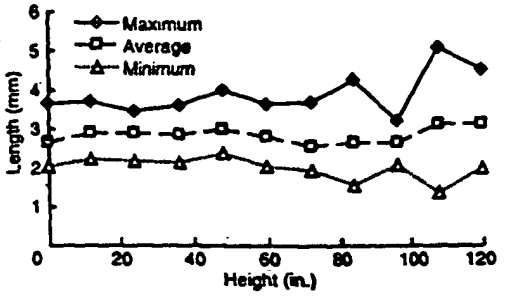

Fig. 5. Length of kenaf fiber at 175 days after planting.

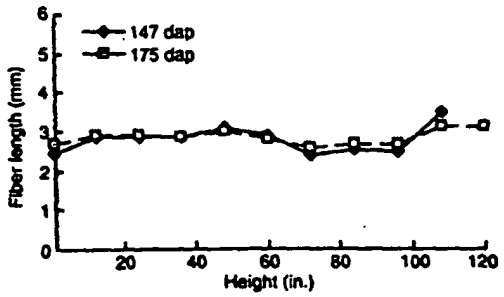

Fig. 6. Average length of kenaf fiber at 147 and 175 days after planting.

kenaf samples as models. Data for red pine and aspen are shown in Tables 8 and 9, respectively; data for kenaf are shown in Fig. 4. Fibers at the center of a selected height were longer than outer fibers. and fibers at the top of the tree were shorter than those at the bottom.

Kenaf stalk samples were taken at different growth stages(147 and 175 DAP), and fiber length was measured every 12 inches(305mm). Fiber length gradually increased from the bottom to the top of the plant. Fiber length also increased as a function of plant growth (Han & Rowell, 1997; Han *et al.*, 1995). The results are shown in Fig. 4 to 6.

Table 8. Two-Dimensional Average Length of Red Pine Fiber.

Distance from pith	Fiber length (mm) at various stalk heights (m)									
(mm)	0.6	2.3	4.0	5.7	7.2	9.8	10.3	11.7	13.1	Avg
0	2.96	3.18	2.98	3.37	3.51	3.77	2.94	3.06	2.30	3.12
25.4	3.42	3.43	3.39	3.45	3.38	2.89	2.54	2.23	1.43	2.91
50.8	3.26	3.04	2.41	2.66	3.21	2.19	2.11	1.84	-	2.59
76.2	2.69	2.53	2.07	2.62	2.52	1.91	1.25	-	-	2.23
101.6	2.08	2.09	1.25	1.17	1.33	-	-	-	-	.1.58
Avg	2.88	2.85	2.42	2.65	2.79	2.69	2.21	2.38	1.87	2.53

Table 9. Two-Dimensional Average Length of Aspen Fiber.

Distance from pith	Fiber length (mm) at various stalk heights (m)									
(mm)	0.5	2.0	3.5	5.0	6.5	8.0	9.2	10.0	10.9	Avg
25.4	1.24	1.20	1.25	1.07	1.02	1.03	1.43	1.07	1.57	1.21
50.8	1.05	1.09	1.11	0.92	0.80	0.80	0.98	0.96	1.34	1.01
76.2	0.99	1.00	0.94	0.79	0.59	-	-	-	-	0.86
101.6	0.91	0.82	0.81	-	-	-	-	-	-	0.85
Avg	1.05	1.03	1.03	0.93	0.80	0.92	1.21	1.02	1.36	1.05

3.3 Distribution of fiber length within plant

To determine the distribution of fibers within the plant, a sample of kenaf was pulped and overall fiber length was measured using the Kajaani procedure. The distribution of kenaf core and bast fibers by length is shown in Fig. 7 and 8, respectively. As Fig. 8 indicates, the distribution of bast fibers was normal: maximum fiber length was about 2.7mm, and fiber length ranged from 0 to 8mm.

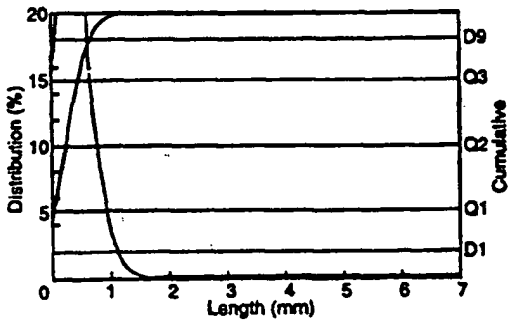

Fig. 7. Weighted distribution of kraft pulped kenaf core fiber.

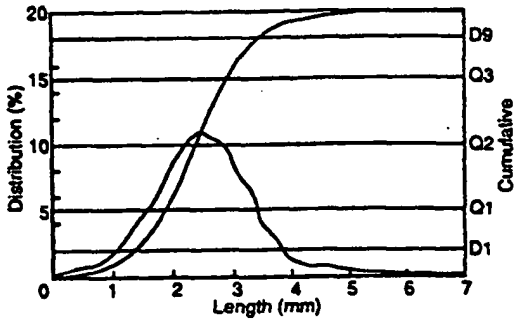

Fig. 8. **Weighted distribution of kraft pulped kenaf bast fiber**

3.4 Crystallinity and Permeability

Table 10 shows crystallinity values of kenaf as a function of growth. The measurements were taken from core and bast fibers of four different cultivars of kenaf. Crystallinity tended to decrease as the plant matured, but the difference between bast and core fibers was inconclusive (Han & Rowell, 1995). The permeability of some common fibers was measured. Kenaf core had the highest permeability, followed by cotton (Fig. 9).

Table 10. Crystallinity of Kenaf as a Function of Growth[a].

DAP	C-108		T-1		E-41		45-9	
	Fiber	Core	Fiber	Core	Fiber	Core	Fiber	Core
56	84.25	78.38	80.77	87.72	78.40	81.08	80.53	82.35
84	78.87	72.13	76.43	73.85	81.48	12.22	77.62	76.92
112	78.91	78.87	73.94	70.63	80.43	71.79	78.32	75.41
140	80.71	72.31	80.29	79.39	78.17	66.93	78.10	68.18
168	73.57	66.93	77.77	65.19	70.90	64.00	74.64	67.19
196	72:34	68.18	72.86	73.11	70.63	69.53	68.38	70.83

[a] Source : Refernce 3.

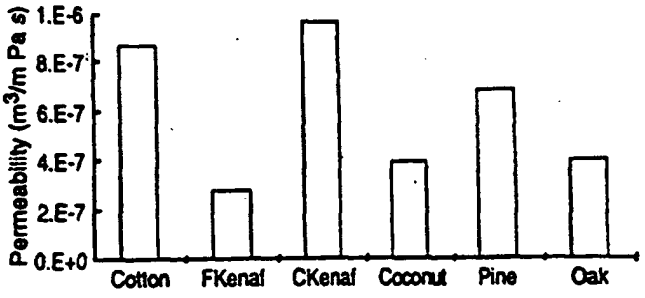

Fig. 9. Permeability values of some common nonwood fibers.

Further research is needed to characterize other physical properties of nonwood fibers. such as density. individual fiber strength. and fiber surface chemistry. Information on such properties will be forthcoming at the 1999 American Chemical Society symposium on advances in analytical methodologies in lignocellulosics chemistry.

4. CONCLUSION

Nonwood fibers have tremendous variations in chemical and physical properties. Of particular importance for pulping are fiber length. lignin content. and cellulose content:

1. Fiber length-Nonwood fibers average 8 mm (flax and hemp) and can be as long as 120 mm (ramie).
2. Lignin content-Lignin content of some nonwood fibers is lower than that of high-yield pulp. Hemp contains about 3% lignin and pineapple and samandoque (*Hesperaloe funifera*) fibers, about 5% lignin. The low lignin content indicates that nonwood fibers will require very mild pulping conditions.
3. Cellulose content-Cellulose content of some non-wood fibers is 80% and higher (cotton, ramie, and hemp).

Finally, since most nonwood fibers are annual plants. variations in chemical and physical properties in a given plant might need to be controlled through agricultural practices.

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REFERENCES

1. Parham, R. A., and H. M. Kausftinen. 1974. Papermaking materials. An atlas of electron micrographs. The Institute of Paper Chemistry, Appleton, WI
2. Han. J. S., and J. S. Rowell. 1997. Chemical Composition of Fibers. Paper and Composites from Agro Based Resources. Rowell, Young, and Rowell, eds., CRC Press. Inc.
3. Han. J. S., W. Kim, and R. M. Rowell. 1995. Chemical and physical properties of kenaf as a function of growth. Proceedings of International Kenaf Association, March 9~10, 1995, Irving, Texas
4. Ilvessalo-Pfaffli, Marja-Sisko. 1995. Fiber Atlas Identification of Papermaking Fibers. Springer : 290. 299
5. Isenberg, Irving H. 1967. Pulp and Paper Microscopy. The institute of Paper Chemistry. Appleton, WI

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